Effects of a breathable silk-like, 3-layer ventilating mattress sheet on self-repositioning, repositioning support and pressure ulcer incidence; a pragmatic observational study



Authors (clockwise from top left): *MWF van Leen, WIJ van Ratingen and JMGA Schols*

Besides pressure relief by using special support surfaces and repositioning, pressure ulcer guidelines on prevention and treatment nowadays also advise on shear force reduction and regulation of the microclimate by using silk-like mattress covers instead of cotton covers. Skincair® (Sense Textile), a newly developed breathable silk-like, 3-layer ventilating mattress sheet, reduces shear forces and is able to absorb excess fluid, which may result in better self-repositioning in bed, reduced nursing repositioning support and enhanced pressure ulcer (PU) prevention. Moreover, reducing the amount of fluid and improving the microclimate may result in lesser damage of the skin overall. A total of 112 residents of eight nursing homes at risk of PU development, participated in a 12-weeks observational study. Residents were selected, based on the following criteria: age >65 year, Braden score <18, laying on standard cotton mattress cover around a preventive mattress and need of nursing support for repositioning. During the first 6 weeks, all 112 residents laid on the cotton sheet (control period) and during the second 6 weeks all residents laid on the new 3-layer ventilating mattress sheet (intervention period) while receiving care as usual. There were no mattress changes during this 12-week period. On the cotton sheet all residents were unable to perform self-repositioning in bed and, therefore, needed nursing support for repositioning. At the end of the 6 weeks intervention period, 69.6% of the residents were able to change their position in bed without nursing support, implicating that the requirement of nursing support for repositioning decreased significantly. The development of pressure ulcers (PUs) was also monitored. In the control period, when residents were laying on the cotton sheet, 22 residents developed 41 PUs (category 2). In the intervention period, two residents developed a category 2 PU and one resident showed deterioration of a category 2 into a category 3 PU. This study showed that the use of the new breathable silk-like, 3-layer ventilating mattress sheet, which acts as the direct patient interface, improved self-repositioning of patients in bed and led to less need for nursing support during repositioning. Moreover, a lower PU incidence was observed.

Author details can be found on p39

The development of pressure ulcers (PUs) continues to be a problem among residents of long-term care facilities (De Souza and De Gouveia Santos, 2010); Meesterberends et al, 2013). Therefore, a strong focus on PU prevention remains necessary.

The European Pressure Ulcer Advisory Panel/ National Pressure Advisory Panel/ Pan Pacific Pressure In Alliance (EPAP/NPUAP/PPPIA): 2019 Prevention and treatment of pressure ulcers/ injuries guideline, defines a pressure ulcer as: "A pressure ulcer is a localised ulcer to the skin and/or underlying tissue usually over a bony prominence, as a result of pressure, or pressure in combination with shear" (EPUAP et al, 2019).

Pressure and shear are the mostly mentioned direct causes of a pressure ulcer (Wounds International, 2010; EPUAP et al, 2019). However, in this article the authors focus on the effects of shear. Shear is often used to summarise the terms shear stress and shear force (Reger et al, 2010; EPUAP et al, 2019).

When forces are produced by both a perpendicular component (pressure) and a parallel component to the skin (shear), the combined forces are called shear forces (Reger et al, 2010). To deal with shear forces per unit area, the term "shear stress" has been introduced. Shear stress also causes tissue deformation.

Friction as a solid factor is no longer mentioned in the description of PU development in the aforementioned EPUAP/NPUAP/PPPIA guideline, but there is a close association with shear. Friction (static and dynamic) is defined as the force that resists the relative motion of two adjacent objects, like skin and support interface. Often friction potentiates shear stress (Wounds International, 2010).

If pressure and shear are applied to the skin, particularly over a bony prominence, this may cause changes of the skin and the underlying tissue. This can result in tissue distortion, compression of blood vessels, stretching and narrowing of the capillary beds, disturbance of the cell metabolism and even cell death.

Related to the specific attention for shear in this article, the additional focus is on the prevention of more superficial category 1 and 2 PUs, but especially category 2 PUs because of widely acknowledged problems with the recognition and reliable diagnosis of category 1 PUs (Bethell, 2003; Nixon et al, 2005; Briggs, 2006).

Superficial PUs (category 2) involve partial-thickness loss of the dermis presenting itself as a shallow open ulcer with a red pink wound bed or as an intact or open/ruptured serum-filled blister. At present, the most important cause of category 2 PUs is attributed to friction and shear forces, while pressure is of less importance (Briggs, 2006; Kottner et al, 2018).

Furthermore, another important contributing factor for PU development, involves the microenvironment or microclimate, including the skin temperature, the moisture regulation and the humidity control at the skin-support surface interface (i.e. the space between the residents skin and the skin contact layer e.g. cotton sheets, silk sheets, mattresses) (Roaf, 2006; Wounds International, 2010; Yusuf et al, 2015; Lechner et al, 2017).

Already, Roaf mentioned in 1976 that the maintenance of a balanced microclimate is a key modifier of the ability of the skin and underlying soft tissue to withstand prolonged superficial shear stress (Roaf, 2006).

PU prevention

Based on the need for pressure redistribution, the EPUAP/NPUAP/PPPIA guidelines recommend using special types of mattresses/cushions together with repositioning (following an individualised schedule, unless contraindicated), in order to prevent PUs (Yusuf et al, 2015)

However, referring to the information and cited literature above, reduction and redistribution of pressure alone is possibly not sufficient enough to reduce damage of the skin and underlying tissues.

Therefore, the guidelines also acknowledge both the importance of reducing the shear forces between the body of the resident and support surfaces (e.g. cotton sheet, silk-like sheet), as well as the necessity of controlling the microclimate (humidity and temperature) near the skin.

Care home residents

Frail and disabled care home residents, who most of the time cannot perform self-repositioning or lift themselves during repositioning, are at high risk for category 1 and 2 PUs caused by friction and shear forces next to pressure (Wounds International, 2010). Both forces commonly occur when residents are transferred, turned or repositioned in bed (Roaf, 2006).

A higher friction of bed mattress covering materials may impede or inhibit self-repositioning (e.g. position change of the individual by turning to relieve or redistribute pressure and enhance comfort). In addition, many residents suffer from incontinence and inappropriate sweating, which leads to a humid environment, increasing friction and shear forces even more (Wounds International, 2010). These aspects also hamper the convenience of turning, executed by nurses even if they are using appropriate moving and handling aides. Subsequently, this may also contribute to a higher PU incidence.

Towards more adequate bed textile

Ideally, the friction coefficient of the bed textile or the resident-mattress interface should be as low as possible to limit friction

***MWF van Leen** is Elderly Care Physician, Ruitersbos, Breda-Netherlands; **WIJ van Ratingen** is Biometrician, WvR research & development, Neer, Netherlands; **JMGA Schols** is Professor of Old Age Medicine, Caphri, Dept. Health Services Research, Maastricht University, Maastricht, Netherlands*

and shear forces on the skin and to diminish the risk of PU development (Roaf, 2006; Wounds International, 2010).

This can be achieved by applying the right type of mattress covering sheets, which are able to decrease friction and shear and also have a positive impact on controlling the microclimate.

Normally cotton sheets are applied as regular mattress covers (EPUAP, 2019). However, the ability of cotton sheets to decrease friction and shear forces in dry and wet conditions is rather limited. This means that, when laying on a bed mattress covered with a standard cotton bed sheet, the ability of the skin-cotton sheet interface, to control the microclimate by quick absorption and evaporation of perspiration is rather limited (Reger et al, 2010).

Moreover, because of the humid and warm environment at the skin/sheet interface caused by sweating or urine, cooling of the skin may be an additional problem (Sae-Sia et al, 2005; Rapp et al, 2009; Yusuf et al, 2015; Lechner et al, 2017). It is known that a higher skin temperature also may be a cause of vulnerable tissue degradation as it results in a higher cell metabolism, leading to skin damage and the occurrence of wounds (Sae-Sia et al, 2005; Rapp et al, 2009; Yusuf et al, 2015; Lechner et al, 2017).

Additionally, the friction coefficient will rise when the skin and/or supporting surface are more moist or wet, leading to an even higher friction and shear stress, which may result in the earlier mentioned skin damage during movements (Clark, 1996; Gerhardt et al, 2008; Williamson et al, 2013).

This makes it evident why guidelines advise to additionally limit the use of traditional cotton mattress sheets for the resident-mattress interface and to use silk-like fabrics (EPUAP et al, 2019). However, when using silk-like fabrics one should pay attention to possible risks of slipping out of bed. An elastic silk-like sheet will be more preferrable, due to its ability to follow the indent of the underlying mattress caused by the weight, shape and position of the patient. Special attention for a higher risk of falls out of bed or during transfers out of bed should also be part of adequate usage instructions.

At this point, it may be clear that new textile materials instead of cotton sheets for covering the initially advised preventive mattresses, may be additionally helpful to reduce PU incidence by realising less friction and shear during self-turning and repositioning, in combination with a better regulation of the microclimate.

Both Rotaru and Smith (2013) measured friction in a laboratory under dry and wet conditions and found a 50% reduction of friction and shear forces on a mattress sheet consisting of 50% cotton, 50% polyester yarns. Their final assumptions were that low friction and beneficial water transport properties may create a better PU prevention (Smith and Ingram, 2010; Rotaru et al, 2013).

Studies done by Coladonato et al (2012), Smith et al and Derler have shown that silk-like fabrics or synthetic fibres sheets, which reduce friction and improve the microclimate of the skin, lead to lower incidence rates of pressure injuries compared to standard cotton sheets.

The company Sense Textile has developed a breathable silk-like, 3-layer ventilating mattress sheet (Skincair®), which is able to reduce skin friction during repositioning and to improve simultaneously poor microclimate conditions by absorbing and evaporating the surplus of fluid *[Figure 1]*. The material consists of refined super micro-polymer fibres, monofilament fibres and elastic fibres, manufactured via a special knitting process into one refined spacer fabric material of 3 mm thickness. The material has a small and smooth diamond-like gliding pattern on the top surface, which aims to ease body movements. The intermediate layer of monofilament fibres consists largely of air, takes up perspiration and vapour, lets it evaporate, creating an active mechanic ventilation driven by opening

Figure 1. Details of the smooth breathable silk-like, 3-layer ventilating mattress sheet (Skincair) around a base mattress (top) and surface structure with diamond gliding pattern and side view material (bottom).

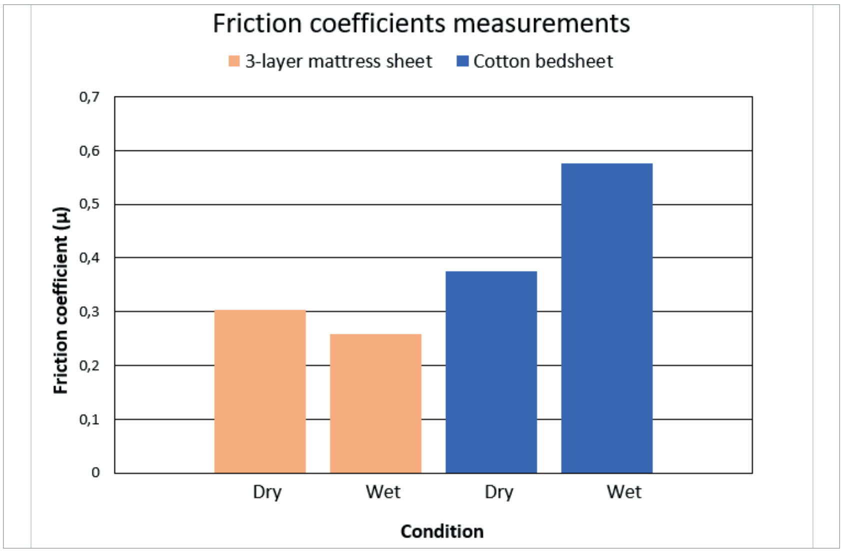

Figure 2. Standard laboratory tests for friction measurement in dry and in wet conditions have shown that on a cotton sheet, the friction coefficient, as expected, rises in wet conditions which results in higher shear forces. On the contrary, on the breathable silk-like, 3-layer ventilating mattress sheet in a dry condition the friction coefficient is already lower and in a wet condition even drops. These aspects are important because a lot of residents suffer from incontinency (urinary and/or faecal), which results in higher shear forces in wet conditions on cotton sheets and, thus, may lead to more PUs. (Friction coefficient measurements (Institute of Textile Technology and Process Engineering Denkendorf, 2016).

and deformation of the fabric through body movements, and resulting in a refined air and moisture transport. Due to the fine knitted and elastic structure, the product can easily adapt to the contours of the body, has a relative low-friction coefficient *[Figure 2]* and forms no folds, wrinkles or other pressure increasing points during use. Skincair is registered as a CE class 1 medical device.

In *Figure 1*, the mattress sheet Skincair is visible with fixation of the sheet around the mattress. The middle picture shows the diamond gliding pattern of the upper layer. The picture also shows the structure of the in-between layer.

Related to the recommendations of the EPUAP/NPUAP/PPPIA guidelines, our hypotheses are that the use of this smooth breathable silk-like, 3-layer ventilating mattress cover will lead to a) better self-repositioning of residents, b) it will facilitate repositioning by nurses and c) lead to less PU development.

In this pragmatic observational study, the authors, therefore, wanted to answer the following research questions:

1. What is the effect on (self)-repositioning ability during a 12-week period in which nursing home residents at risk of PUs are cared for on subsequently a cotton mattress sheet (first 6 weeks) and a breathable silk-like, 3-layer ventilating mattress sheet (second 6 weeks)?
2. What is the pressure ulcer incidence during a 12-week period when nursing home residents at risk of PUs are cared for on subsequently a cotton mattress sheet (first 6 weeks) and a breathable silk-like, 3-layer ventilating mattress sheet (second 6 weeks)?

Methods

Design

A longitudinal, observational study was performed in eight care homes, following a pre-post pragmatic cross-over design.

Sample

Residents were selected, based on the following inclusion criteria:

1. Age >65 years
2. At risk of PU development (Braden scale score <18)
3. Residing for more than 3 months in the care home
4. Use of a preventive pressure reducing mattress according to protocol with a surrounding cotton mattress sheet
5. Not able to perform self-repositioning
6. Needing support of one or two healthcare professionals during repositioning
7. Informed consent by resident or legal representative.

Exclusion criteria:

1. Life expectancy of less than 6 weeks

Procedure

Each participating resident has been monitored for a total of 12 weeks. At the request of the monitored resident or legal representative, participation could be stopped at any moment. Study participation also stopped if the resident was admitted to a hospital or when changes in preventive measures (e.g. mattress change, stopping repositioning) were necessary.

Intervention

After signing informed consent all participating residents started the pre-intervention phase for a period of 6 weeks in which they slept on a regular cotton sheet covering their regular mattress (control period), directly followed by a period of 6 weeks on the breathable 3-layer mattress sheet (intervention period).

Data collection

Trained tissue viability nurses, working in the care homes, were responsible for data collection; one for each care home.

At start of the study, the following data were recorded in a Case Record Form (CRF) for each participating resident: age, gender, main diagnosis, height, weight, Body Mass Index (BMI), presence of incontinence (as recorded in patient file), the extent of (self-) repositioning in bed, measured by using the sub scale mobility of the Braden scale and by recording the need for help during repositioning by one or two nurses. In addition, the total Braden scale score was assessed. The Braden scale is a risk score for evaluating the patient's risk for developing a PU. It measures aspects of sensory perception, skin moisture, activity, mobility, nutrition and friction and/or shear. Scores less than 18 indicate a risk of PU development (NPUAP et al, 2014).

At start of the study (T0) and at the end of week 6 (T1) and 12 (T2), PU-presence/incidence and PU category, the extent of self-repositioning in bed and the need for help during repositioning were all assessed as main outcome parameters.

Power calculation

To detect a clinically relevant reduction of the PU incidence of 30% with a statistical safeguard of α 0.05 and a power of 0.80, 95 residents for each period were needed.

Statistical analyses

Statistical analyses were conducted by using SPSS (IMB SPSS Statistics 21.0). The Wilcoxon signed rank test, a statistical test used on paired and unpaired data was performed to determine the differences in PU development and need for help during repositioning. Ninety-five per cent confidence intervals were calculated. Statistical significance was reached for a *P*-value <0.05.

Ethical considerations

The study protocol was approved by the Central Committee on Research involving Human Subjects (CCMO, Netherlands), date 20190404.

Results

A total of 112 residents were included and could be monitored until the end of the study. Around half of the residents suffered from diseases with associated cognitive problems, such as dementia and neurological diseases. In these cases their representatives signed for informed consent.

In *Table 1*, the baseline characteristics of the participating residents are presented.

The mean age was 84.2 years old, 67% was female and the mean BMI was 24.9. The average profile of the residents fitted in the general profile of Dutch care home residents (Braden and Bergstrom, 1994).

Table 2 shows the results regarding self-repositioning and need for nursing support

Table 1: characteristics of participating residents.

Resident characteristics at start of study	Test group averages and totals
Number of residents	112
Mean age in years, (oldest and youngest)	Mean 84.2 years, (98 and 48)
Gender	Men: 37, women: 75
Height (mean)	166.2 cm
Weight (mean)	71.5 kg
BMI (mean), lowest and highest	25.4
Urine Incontinence Y/N	10
Urinary catheter use Y/N	5
Main diagnoses	
Dementia	21
Parkinson's disease	10
CVA/stroke/paraplegia	18
Long diseases	8
Cardiovascular diseases	18
Diabetes	9
Other diagnoses related to musculoskeletal system	11
Other diagnoses related to cerebral/neurological diseases	7
Psychiatric diseases	3
Dermatologic diseases	3
Cancer	4

Table 2: Self-repositioning and nurse supported repositioning; * Wilcoxon singed rank test.					
Residents (*n*=112)	**At start of study**	**Cotton sheet (at end control period of 6 weeks)**	**New breathable 3-layer ventilating mattress sheet (at end intervention period of 6 weeks)**	***P*-value***	**95% CI**
Self-repositioning	112 participating residents (100%) were not able to perform self-repositioning	112 participating residents (100%) were not able to perform self-repositioning	78 of participating 112 residents (69.6%) can perform self-repositioning; 34 residents (30.4%) are still unable to perform self-repositioning	<0.001	0.013 (0.002 – 0.090)
Nurse handling needed for repositioning during night and day by two nurses	90 of the 112 participating residents (80.4%) needed the help of two nurses	90 of the 112 participating residents (80.4%) needed help of two nurses	20 of the participating 112 residents (17.8%) needed the help of two nurses; 64 residents (57.1%) needed help of one nurse six residents (5.4%) did not need nursing support anymore.	<0.001	4.500 (3.057 – 6.623
Nurse handling needed for repositioning during night and day by one nurse	22 of the 112 participating residents (19.6%) needed the help of one nurse	22 of the 112 participating residents (19.6%) needed the help of one nurse	21 of the participating 112 residents (18.7%) needed the help of one nurse; one resident (0.9%) did not need nursing support anymore.	<0.317	0.957 (0.064 – 14.368)

Table 3: PU incidence during study.				
Residents (*n*=112)	**Cotton sheet (at end control period of 6 weeks)**	**New breathable 3-layer ventilating mattress sheet (at end intervention period of 6 weeks)**	***P*-value***	**95% CI**
Directly developed PUs cat 2	13	1	0.001	0.881 (0.816–0.951)
Cat 2 PUs developed via starting cat 1	28	1	<0.001	0.733 (0.649–0.827)
Developed PUs cat 2 to cat 3	0	1	0.317	1.000 (0.973–1.028))
Total PUs cat 2	**41**	**2**	**<0.001**	**0.610 (0.519–0.717)**
Total PUs cat 3		**1**	**0.317**	**1.000 (0.973–1.028)**

Table 4: location developed cat 2 Pus		
Location	**First 6-weeks on cotton mattress sheet**	**Second 6-weeks on new breathable 3-layer mattress sheet**
Pelvic region	19	3
Outer malleolus	5	0
Heel bone	16	0
Shoulder	1	0
Total amount PU cat 2	**41**	**2**
Total amount PU cat 3		**1**

for repositioning at start, after 6 and 12 weeks. There was no difference in level of self-repositioning at start and after 6 weeks. Self-repositioning means that a resident is able to self-perform small movements, though not always complete self-turning in bed.

Table 2 shows a statistically significant improvement of self-repositioning capability from 0% to 69.6% and a significant reduction in intensity of nurse handling needed for repositioning.

At the end of the study period, only 20 residents needed help from two nurses compared to 90 at the pre-intervention period. In *Table 3*, PU category 2 incidence during the study is presented.

In the control period of the first 6 weeks, in total 41 new category 2 PUs developed (12 residents developed one, four residents two and seven residents 3 category 2 PUs).

In the second period of 6 weeks (intervention period) two new category 2 PUs (one directly and one via category 1 to 2) developed and one resident with a category 2 PU after the control period showed a progression towards a category 3 PUs. The other 40 category 2 PUs present at the end of the control period showed a nice healing tendency during the intervention period. Overall, PU incidence differed significantly (*P*=<0.001 {0.519–0.717}) between the control period and the intervention period.

Table 4 shows the body sites where category 2

PUs developed during this study.

All new PUs developed at body locations where the residents' skin was in contact with the sheet on top of the preventive mattress.

Discussion

All residents who participated in this study were initially, when laying on a cotton sheet covering their mattress, unable to manage self-repositioning in bed and needed help for repositioning by one or two nurses. Repositioning is a widely known and acknowledged measure for prevention of PUs and is necessary, when residents are not able to move in their beds themselves, mostly caused by severe mobility problems (Ing and Hoefsmit, 2016; EPUAP et al, 2019). Application of repositioning, however, results in a high workload for the nursing staff and often causes discomfort for residents. As *Table 2* shows, in the intervention period a considerable reduction of nursing support needed for repositioning occurred.

Moreover, during application of the new breathable, 3-layer ventilating mattress sheet a significantly better self-repositioning performance was observed among 69.6% of the participating residents.

Because of the high friction coefficient on a cotton sheet, repositioning often requires help from two nurses. The much lower coefficient of the 3-layer sheet makes the force needed for repositioning much lesser and that's why in the group who initially needed help from two nurses (90 residents) at the end of the 12-week study 64 residents needed help from one nurse and 6 residents were able to change position in bed without any help.

In the second group of 22 residents all needed help from one nurse; at the end of the second 6-week period still 21 residents needed help from one nurse and only one resident was able to change position without any help.

It is clear that to re-achieve the ability to full self-repositioning, more is needed than only diminishing the friction coefficient (e.g. training to acquire more muscular strength and better coordination).

Unfortunately, there are currently no studies about the effects of repositioning in relation to different types of mattress sheets. All studies included in a systematic review from Gillespie et al (2014) on the effects of different types of mattress sheets, only looked at the physical impact for nurses and time patterns (Gillespie et al, 2014).

All residents who participated in this study were at high risk (based on clinical view in combination with Braden scale scores) for PU development and the results of this study show that in the 6-week control period, in which residents were laying on a cotton sheet, overall category 2 PU incidence indeed was fairly high.

This fits with the results of the study of Meesterberends et al (2013) who also reported a high PU incidence in nursing homes over a rather short period (Meesterberends et al, 2013).

On the contrary, during the 6-week intervention period when residents were laying on the silk-like 3-layer mattress sheet, only two new category 2 PUs developed. These findings fit in the results of other studies, which have shown that silk-like fabrics or synthetic smooth fibre compared to 90 at the pre-intervention period sheets may lead to lower incidence rates of pressure ulcers compared to standard cotton bed linen materials (Coladonato et al, 2012; Derler et al, 2012; Smith et al, 2013; Institute of Textile Technology and Process Engineering Denkendorf, 2016).

Though this study shows interesting outcomes, there are limitations related to its pragmatic observational design and therefore, the observed effects should be further evaluated in a larger randomised controlled trial.

Conclusion

During the use of a breathable silk-like,3-layer ventilating mattress sheet in this study, self-repositioning improved and a lower PU incidence was observed. In addition, the need for nursing support during repositioning decreased. WINT

Conflicts of interests

Researchers, authors and participating care homes did not receive a financial compensation. The used materials were purchased by the participating care homes.

References

Bethell E (2003) Controversies in classifying and assessing grade I pressure ulcers. *J Wound Care* 12(1): 33–6

Braden BJ, Bergstrom N (1994) Predictive validity of the Braden scale for pressure sore risk in a nursing home. *Res Nurs Health* 17(6): 459–70

Briggs S-L (2006) How accurate are RGNs in grading pressure ulcers? *Br J Nurs* 15(22): 1230–4

Clark M (1996) The aetiology of superficial sacral pressure sores. In: Leaper D, Cherry G, Dealey C et al (eds.) *Proceedings of the 6th European Conference on Advances in Wound Management*. Amsterdam: McMillan Press pp167–70

Coladonato J, Smith A, Watson N et al (2012) Prospective, non- randomized controlled trials to compare the effect of silk-like fabric to standard hospital linens on the rate of hospital acquired pressure injuries. *Ostomy Wound Manage* 58(10): 14–31

De Souza DM, De Gouveia Santos VL (2010) Incidence of pressure ulcers in the institutionalized elderly. *J Wound Ostomy Continence Nurs* 37(3): 272–6

Derler S, Rao A, Ballistreri P et al (2012) Medical Textiles with low friction for decubitus prevention. *Tribology International* 46(1): 208–14

Gerhardt LC, Strässle V, Lenz A et al (2008) Influence of epidermal hydration on the friction of human skin against textiles. *J R Soc Interface* 5(28): 1317–28

Gillespie BM, Chaboyer WP, McInnes E et al (2014) Repositioning for pressure ulcer prevention in adults. *Cochrane Database Syst Rev* 2014(4): CD009958

Ing D, Hoefsmit MBA (2016) Beleidsregels Indicatiestelling Wlz 2016. Utrecht: CIZ Available at: https://bit.ly/34oZ830 (accessed 01.02.2022)

Institute of Textile Technology and Process Engineering Denkendorf (2016) *Test Results NR.E-0076-TT-16*. Available at: https://skincair.nl/innovatie-onderzoek/ (accessed 11.02.2022)

Kottner K, Black J, Call E et al (2018) Microclimate: A critical review in the context of pressure ulcer prevention. *Clin Biomech (Bristol, Avon)* 59: 62–70

Lahmann NA, Kottner J (2011) Relation between pressure, friction and pressure ulcer categories: A secondary data analysis of hospital patients using CHAID methods. *Int J Nursing Stud* 48(12): 1487–94

Lechner A, Lachmann N, Neumann K ET AL (2017) Dry skin and pressure ulcer risk: A multi-center cross sectional prevalence study in German hospitals and nursing homes. *Int J Nurs Stud* 73: 63–9

Meesterberends E, Halfens RJG, Spreeuwenberg MD et al (2013) Do residents in Dutch nursing homes have more pressure ulcers than residents in German nursing homes? A prospective multicentre cohort study. *J Am Med Dir Assoc* 14(8): 605–10

Nixon J, Thorpe H, Barrow H et al (2005) Reliability of pressure ulcer classification and diagnosis. *J Adv Nurs* 50(6): 613–23

Rapp MP, Bergstrom N, Padhye NS (2009) Contribution of skin temperature regularity to the risk of developing pressure injuries in nursing facility residents. *Adv Skin Wound Care* 22(11): 506–13

Roaf R (2006) The causation of preventing bedsores. *J Tissue Viability* 16(2): 6–8

Rotaru GM, Pille D, Lehmeier FK et al (2013) Friction between human skin and medical textiles for decubitus prevention. *Tribology International* 65(2013): 91–6

Sae-Sia W, Wipke-Tevis DD, Williams DA (2005) Elevated sacral skin temperature (Ts): a risk factor for pressure ulcer development in hospitalized neurologically impaired Thai residents. *Appl Nurs Res* 18(1): 29–35

Smith G, Ingram A (2010) Clinical and cost effectiveness evaluation of low friction and shear garments. *J Wound Care* 19(12): 535–42

Smith A, McNicholl LL, Amos MA et al (2013) A retrospective, nonrandomized, before and after study of the effect of linens constructed of synthetic silk-like fabric on pressure ulcer incidence. *Ostomy Wound Manage* 59(4): 28–34

The National Pressure Ulcer Advisory Panel, European Pressure Ulcer Advisory Panel, Pan Pacific Pressure Ulcer Alliance (2014) *Prevention and Treatment of Pressure Ulcers. Clinical Practice Guideline*. Cambridge Media: Osborne Park, Western Australia. Available at: https://bit.ly/3IZS385 (accessed 01.02.2022)

The European Pressure Injury Advisory Panel, National Pressure Advisory Panel, Pan Pacific Pressure Ulcer Alliance (2019) *Prevention and Treatment of Pressure Ulcers/Injuries: Quick Reference Guide 2019*. Available at: https://bit.ly/3rhmErm (accessed 31.01.2022)

Williamson R, Lachenbruch C, VanGilder C (2013) Laboratory study examining the impact of linen use on low air-loss support surface heat and water vapor transmission rates. *Ostomy Wound Manage* 59(8): 32–41

Wounds International (2010) *International Review. Pressure Ulcer Prevention: Pressure, Shear, Friction and Microclimate in Context. A Consensus Document*. London: Wounds international. Available at: https://www.woundsinternational.com/resources/details/international-review-pressure-ulcer-prevention-pressure-shear-friction-and-microclimate-context (accessed 31.01.2022) pp1–26

Yusuf S, Okuwa M, Shigeta Y et al (2015) Microclimate and development of pressure injuries and superficial skin changes. *Int Wound J* 12(1): 40–6